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AERIAL PROTECTION OVER THE SEAS

NATURAL PHILOSOPHY

A non-technical discussion of the Atomic Theory in the light of the Uncertainty Principle.

By THOMAS H. OSGOOD

MODERN atomic theories well warrant the readoption by physics of its old name, Natural Philosophy, the philosophy of Nature. The fundamental ideas in these theories differ vastly in character from the old concepts of velocity, acceleration and the like whose acquaintance we make in a first course in physics. In this article we shall discuss some of these ideas and their bearing on atomic theory in terms understandable to the layman.

The planetary nature of atoms—a heavy central nucleus, positively charged, surrounded by groups of light, negatively charged electrons,—was first proven some twenty years ago. Since that time experience has shown that ordinary mechanics, founded on Newton's laws of motion, by which we compute such things as the speeds of trains and the centrifugal forces which rails must resist on curves, when applied to atomic systems, frequently predict results which are not quite in harmony with the results of test experiments. The reason is that the problems which arise in dealing with massive bodies are not of the same kind as those which occur in the realm of individual atoms. The important point is that the necessary information in dealing with a simple mechanical system is obtainable easily, with the help of metre sticks, microscopes, clocks, balances and other laboratory apparatus, and with an accuracy whose limit is set by the fineness of the instruments available.

In the case of a single atom we are faced with a difficulty at the outset. It is *not* possible to collect the preliminary information, simply because that would involve making measurements upon the atom. This in itself cannot be considered as a stumbling block, for although the kind of measurement in question is not always feasible in practice, yet it is always possible theoretically. The real difficulty is that every such observation disturbs the atom so that, an instant later, its configuration is no longer a natural sequel to its former state. Hence it is not possible to gather all the information about the initial state of an atomic system which an application of Newtonian mechanics would demand. To make this clearer, let us examine more closely what is meant by making an observation of the position of an object. Suppose that we wish to turn on the electric light. The first thing is to locate the switch. In daylight, one glance is enough to furnish a mental picture of its position. In darkness, we must grope about, feeling along the wall, until one hand strikes the knob. In the first case, the real agent which gives information about the switch is the daylight which is scattered by the switch into our eyes. In the second case, similar information reaches us through the behavior of a material probe (the hand) which, partly by chance, collides with the object of our search.

Another analogy which more nearly fits the atomic case can be constructed thusly. Suppose that on a billiard table in a dark room there is, somewhere, a red ball. To find its position, the simplest thing to do would be to take a flashlight from your pocket and explore the table top. Another possible way would be to stand at one corner and roll a white ball in various directions until it collided with the red one. It is easy to see the parallelism between the fundamental methods of these two analogies. Similarly, the process of observing a small particle such as an electron consists fundamentally in allowing light or another electron to interact with it. From the nature and direction of the scattered light or scattered electron, the original position of the electron is inferred. But the scattering process disturbs the object sought, as is obvious in the case of the billiard balls. We know, indeed, where the red ball *was,* but not where it *is.*

When we descend to objects comparable in mass with an electron, the effect of the beam of light which helps our search may be just as disturbing as the effect of one billiard ball on another. For a beam of light carries momentum, and when a single particle of light, or photon, as it is called, collides with an electron, it transfers to it some of its momentum. The electron therefore speeds off. Again we know where it *was,* but not where it *is.*

Imagine now that we wish to follow a particular electron as it revolves about the nucleus in a single atom. There are two ways of finding where it is at any instant. Either we can shoot other electrons at it, and watch in which direction one bounces off which has been lucky enough to hit the atomic electron; or we can do the same things with photons (*i.e.,* a beam of light). In either case, the electron whose path we are investigating is knocked out of its normal course and the experiment fails, for the atom is no longer fit for subsequent investigation. It is as though a toy train were running on a closed track in a dark room, and that some means were available for switching on a light (say in the cab) so that its position could be observed. If, as soon as we pressed the switch, and every time we pressed it, the train fell off the track, we should have a good imitation of the process of trying to observe an electron in an atom.

The best that can be done, therefore, is to find the position of an electron in each of many similar atoms. This gives, of course, very little information about *one* atom, although it reveals the average behavior of an electron in atoms of the same kind. Any theory, then, which deals with atoms, should deal with averages and probabilities rather than with the certainties which are familiar in ordinary dynamics; that is, it should be a statistical theory. Recently, an atomic theory called wave-mechanics has been devised which fulfills this requirement; it can predict correctly the probability of the occurrence of a specified configuration of an atom, or it can predict the most probable state of an atom. This limited power of the theory must not, however, be regarded as a fault, but rather

as a recommendation, since predictions of such average are the only ones which can be tested by experiment.

Why then, it is natural to ask, is there one kind of mechanics for atoms, and another kind for large bodies, which are built up of millions of atoms? The question can not be answered here; but an inkling of the necessity of having two theories can be gained by remembering that the temper of a mob and the temperament of one individual are usually very different.

II.

It is commonly believed that the accuracy of a *group* of measurements is limited only by the precision of the measuring instruments. From a practical point of view this is true, when dealing with objects of reasonably large size. But it is dangerous to assume that it must be true also in the atomic world. Imagine that a physicist desires to find out by an experiment the position of an electron *and* how fast it is moving. The most accurate method in common use for observing small objects is to look at them with a good microscope. Of course, an electron could never actually be seen with an ordinary microscope, but as the experiment which the physicist performs is identical in principle with the process of using a microscope, we can understand it more easily in the better known case. The actual investigator is not the microscope, but the light which passes through it. Light from a convenient source is thrown on the objects to be examined; the objects scatter the light, some of which is collected by the microscope objective, and focussed in the focal plane of the eyepiece. There the observer sees, not the objects themselves, but a picture which is built up by the interaction and interference of the scattered light, and from this picture the experimenter deduces mentally the sizes, positions and shapes of the objects he is examining.

The size of the smallest object which can be distinguished clearly by a miscroscope depends greatly on the kind of light which is used. This implies, too, that the accuracy with which the position of a point can be located varies with different kinds of light. If we wished, as a practical illustration, to measure the length of this page, correct to the nearest thirty-second of an inch, we should naturally choose a ruler whose smallest graduations were not greater than one thirty-second of an inch. Similarly, in the optical case, the limit of accuracy in locating a point is the wave-length of the light which is used,—the wave-length playing the part, roughly, of the smallest divisions on the ruler.

Now let us return to watch the physicist at his problem. It would not be out of place for you to suggest to him that since visible light has rather a long wave-length, he could fix the position of the electron much more accurately if he used, instead, x-rays, which have a wave-length some thousands of times smaller. He would thank you, agree that it was a good suggestion, and remark that by adopting it he could fix the position of the electron with an error not greater than about 10^{-8} cm. He might mention casually that there would be difficulties in the construction and use of an x-ray microscope, but that these were of secondary importance at the moment. The experimenter would probably remind you that his problem was not just

Photograph by P. M. S. Blackett.

Cloud chamber photograph of Alpha Particles and of a Recoil track in oxygen. One particle has collided with the nucleus of an Oxygen Atom, which recoils, producing the short spur track. The longer spur is the track of the Alpha Particle, continuing on its way after collision.

locating the electron but also knowing how fast it was going. And he would perhaps give you a short lecture in the following vein.

One thing has been overlooked. What effect does the light have on the electron's motion? It was pointed out earlier that when a single particle of light, or photon, strikes an electron and is changed in direction, then momentum is transferred from the photon to the electron, just as in a collision of billiard balls. The electron's velocity will therefore suffer a change. Now an x-ray photon carries thousands of times as much momentum as one of visible light. If much of this is transferred to the electron, as it must be in a successful observation, the electron "recoils", as we say, thousands of times as fast after being struck by an x-ray photon as it does after scattering a photon of visible light. The dilemma is now apparent. If visible light is used to find the electron, no great accuracy of position can be attained, but there is some satisfaction in knowing that the particle is not moving away very fast; on the other hand, if great accuracy of position is desired, an x-ray photon must be used, and the electron speeds away with enormous velocity, ploughing its way through thousands of atoms before it finally comes to rest.

This curious situation might be called the see-saw of physics; the more we know about the electron's position, the less we know about its momentum, and vice versa; for we can never tell exactly in which direction the electron will shoot off, nor exactly how much its velocity has changed. This is because the aperture of our microscope is finite, and cannot be made very small without introducing insurmountable difficulties. Actually, the dilemma is known by the dignified title of the Uncertainty Principle. It can be shown readily that the uncertainty in the possible knowledge of position, and the corresponding uncertainty in momentum (which involves velocity) are mathematically connected. In fact, a formal statement of the uncertainty principle would run somewhat as follows: If the uncertainty in the measurement of position of any body is a, and if the uncertainty in the corresponding momentum is b, then $ab = h$, a constant. So, like the see-saw, if a goes up, b goes down, since their product is constant.

And what of this constant h? It has the same value as the h of the quantum theory—a kind of magic number which, since the beginning of this century, has had to be introduced into atomic calculations to make the results agree with the experimental findings. The arguments of this article provide a new mental picture of h, something that is connected with the fundamental limits of accuracy in the process of observation. Hence, h is losing a little of its mystery but none of its importance, and perhaps, someday, we shall know so much about h that it will make us laugh to look back on the ignorant thirties; in exactly the same spirit as the cigarette advertisement which runs, "It's fun to be fooled, but it's more fun to know."

THE PUBLIC WORKS ADMINISTRATION

By CLARENCE McDONOUGH '12
Director of Engineering
Public Works Administration

OUR country has been passing through the greatest economic crisis ever known, but President Roosevelt has taken the leadership and is enlisting and marshalling resources so that we may again enjoy prosperity.

His first great task was the rehabilitation of the banking system.

His next task was enlisting 300,000 unemployed young men and appropriating some five hundred million dollars to set them to work on tasks of reforestation, reclamation and flood control that in due time will repay for the present outlay.

The greatest was, however, the vast Public Works Program, setting up $3,300,000,000 to fight this depression, create jobs and so increase the buying power of our own working public.

There are various types of undertakings for which this money is available. These are all coordinated in what is known as the Public Works Administration. The Public Works program which includes the construction programs of the various Federal Departments, the $400,000,000 Federal Road program, also includes the making of loans to states and municipalities to aid them in carrying on their projects.

Under the law the Federal Government will contribute up to thirty percent of the total labor and material costs of any approved state or municipal project. The state or municipality will have to furnish the additional funds. Although the Federal Government may, under the Act, loan any part of this balance required, it will not do so, unless the borrower is in a sound financial condition, can furnish good security to the satisfaction of the Public Works Administration, or that said project is self-liquidating. However, any state or municipality prepared to deliver good bonds, within its limit of indebtedness, to cover whatever loan it may seek from the Federal Government, or any revenue producing project, the cost of which can be liquidated from the revenues produced, will be seriously considered.

The Special Board for Public Works has determined upon 4% as a fair interest charge for funds loaned on any state or municipal project. It is demanded that the amount so loaned be amortized within the reasonable life of the project; but in no case shall the amortization exceed a period of more than 30 years.

The country has been divided into ten regions, each region consisting of a number of states suitably grouped for temporary administrative purposes. For each region a man has been appointed and is designated as the Regional Advisor. Each state has an Advisory Committee of three. All projects within the state must be presented to the State Advisory Committee. The duties of this committee are carefully to study the projects presented and send only those conforming to the laws and most worthy of consideration to the headquarters in Washington for final consideration.

Where the State Engineer and the State Advisory Committee disagree on recommendations, reasons for disagreement must be reported by them to Washington.

The Public Works Administration in Washington will pass upon all projects and reserves the right to reject any project and retain full jurisdiction over all Federal projects.

Contracts under the Public Works Administration are required to be given to the lowest responsible bidder. It is the desire of the Public Works Administration so far as possible to authorize the building of public works in or near the greatest centers of unemployment.

The Special Board of Public Works has made a special appropriation to enable the Department of Labor to set up labor employment bureaus throughout the entire country. This is to be administered by the Department of Labor. These bureaus will make it possible to secure the right class of labor, assure an equitable distribution of labor, prevent all discrimination against any class of labor or in any way show favoritism to any particular group.

The State Engineer preparing applications for loans from the Federal Government will present briefly but completely the analysis of the application with such engineering, legal and financial assistance as may be found necessary.

(a) Necessity and social desirability
(b) Economic desirability
(c) Technical soundness
(d) Legal authority of applicant to construct, operate, incur the proposed obligation, and issue the necessary evidence of indebtedness.
(e) Assurance that proposed loan is reasonably secured as will be satisfactory to the Administrator.

The engineer examines and checks the estimated costs as presented by the applicant to assure and certify that the project can be completed within the estimated figure submitted by the applicant. In cases where the engineer disagrees with the applicant's estimate as either too high or too low on the basis of provisions in the National Industrial Recovery Act the estimates of costs will be revised in accordance therewith.

This form is indicative only and will not in any way restrict the engineer in the preparation of a report in setting forth the essential features in such a manner as to give the Administrator a clear picture of the project.

In cases where engineer, financial and legal examiners are employed, the report is jointly prepared, each examiner being responsible within his technical jurisdiction. When the report is completed it is signed by the State Engineer and by the Chairman of the Advisory Board, then transmitted with all exhibits and all data submitted by applicant to the Public Works Administration in Washington.

The application in triplicate forwarded to the Public Works Administration in Washington is recorded and one copy distributed to each of the engineering, financial and legal divisions.

(*Continued on page 163*)

LONG-RANGE WEATHER FORECASTING

The Sun's Effect on Weather

By CHARLES G. ABBOT '94, D.Sc., LL.D.
Secretary, Smithsonian Institution

I ONCE saw a striking illustration of the fickleness of weather while operating a solar observatory on Mount Harqua Hala, in Arizona. I awoke at midnight of a lovely night. The December moon was shining brightly upon a scene so still and charming that I arose and stepped out to enjoy the charm of it. Not a leaf moved. Not a cloud was in the sky. The air seemed almost balmy despite the wintry season. To make a record I pitched a game of horseshoes by the midnight moon. Next morning we awoke with amazement to see the ground covered with 8 inches of snow!

Yet if we fix our thoughts on the temperature, which is in some respects the primary element of weather, perhaps we ought rather to say "constant as the weather". Fundamentally, temperature begins at the absolute zero where molecular motion stops, rather than at the freezing point of water where the Centigrade scale begins. Measured on the absolute Fahrenheit scale, our ordinary temperatures range between winter and summer from about 480° to 550°. A change of 5° F. is large and 15° F. extraordinary in the departure of the mean temperature of any month from the normal. These departures, however, are only 1 to 3 per cent in absolute temperature. Precipitation is much more variable. Its usual range extends from 0 to 300 per cent of normal monthly precipitation.

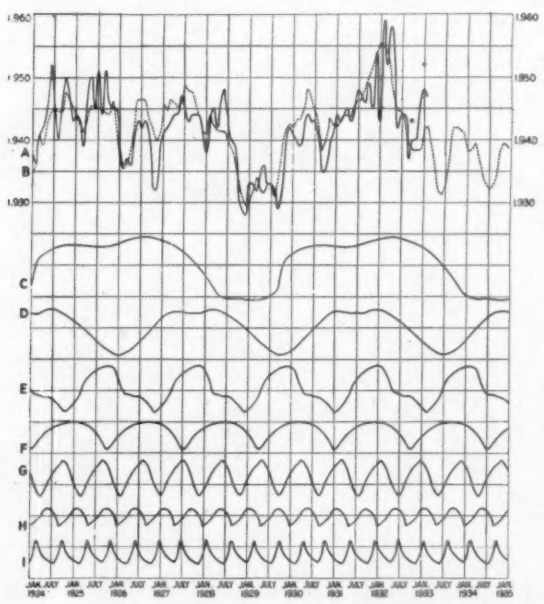
Both the temperature and the precipitation are of such great moment to nearly everybody that farmers, tradesmen, hotel proprietors, electrical manufacturers, and transportation companies would all value highly trustworthy forecasts of the weather of future seasons.

After many disappointments, most official meteorologists of the world are pessimistic as to the possibility of long-range forecasting. Like the irregular flow of a rapid river over stones, they conceive that the weather depends on such complex interactions of the turbulent atmosphere that it is probably unpredictable for more than a few days in advance.

For some years a few of us have believed that the departures from regular normal climates, called weather, are largely governed by changes in solar radiation and that some of these changes are of a periodic nature. Nevertheless these periodic fluctuations of solar heating are so numerous and complexly superposed that it seemed for some time likely to be as difficult to make use of them for forecasting as the meteorologist conceive the prediction of atmospheric influences to be. I have recently become convinced that most of these solar periodicities have their least common multiple in 23 years, or 276 months. Therefore the combination of their effects tends to repeat itself in detail each 23 years. In short the weather submits to a master solar cycle of 23 years which produces and embraces many subordinate features.

It has been said repeatedly by critics that the variation of the sun, even if existant which many still doubt, is so small as to be negligible for the weather. They say that if a room were illuminated by 500 lamps, the extinguishment of one, two, or even five or ten of them would be imperceptible. Similarly, they say, solar variations ranging from one fourth of one per cent up to one or two per cent cannot be important for the weather.

It may be replied that the temperature changes in



Illustrations courtesy Smithsonian Institute.

Figure 1—The variation of the sun. Curve A, original observations by Smithsonian stations. Curves C, D, E, F, G, H, I, periodicities of 68, 45, 25, 21, 11, 8 and 7 months, respectively. Curve B, summation of all the constituents, C-I inclusive.

Figure 2—Departures from normal temperature. Clanton, Ala. A: Observed departures smoothed to 5-month running means. C to L inclusive: Periodicities respectively of 8, 9½, 11, 16, 18, 21, 25, 33, 45, 68 months. B: Residual from A after removing the summation of periodicities C to L. The smooth curve in B shows an 11-year period with maximum at sunspot minimum and about 1° F amplitude.

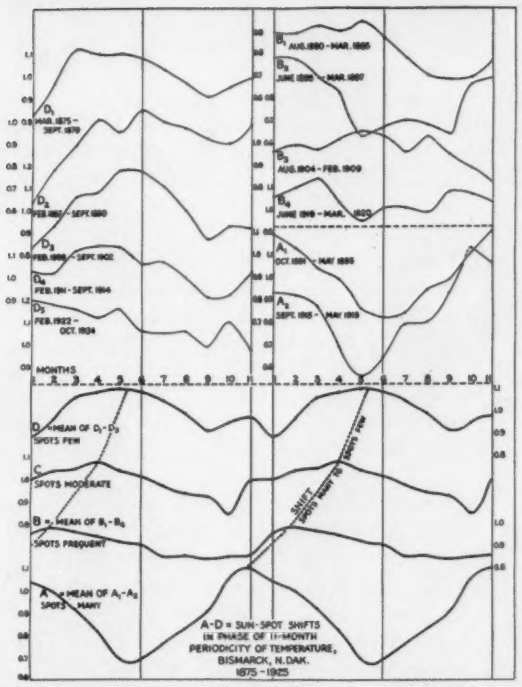


Figure 3—The 11-month periodicity in temperature departures at Bismark holds unchanged in phase through 50 years, if we segregate the data into groups of equal sunspot activity, but shifts phase with altering sunspot frequency.

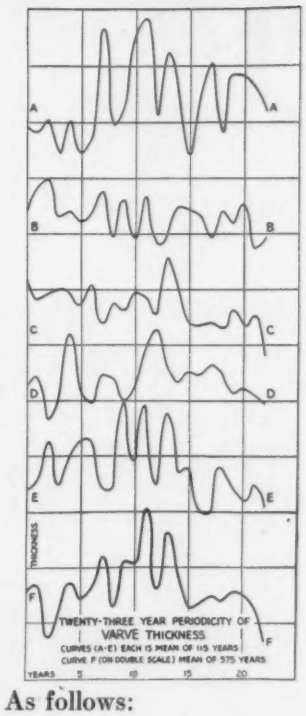

TWENTY-THREE YEAR PERIODICITY OF VARVE THICKNESS
CURVES (A-E) EACH IS MEAN OF 115 YEARS
CURVE F (ON DOUBLE SCALE) MEAN OF 575 YEARS
YEARS

Figure 4.

weather are after all of the same order in percentage as the variations of the sun. Also there are indirect effects like cloudiness which may magnify the effects produced on weather by solar changes. But the best answer is not theoretical inference but practical observation. It is well known that there are worldwide changes of temperature and precipitation of considerable magnitude attending the sunspot cycle of 11 years. Yet at maximum the sun spots do not cover more than 1/500 of the sun's visible disk, and our best series of measurements of the solar constant of radiation, made at Montezuma, Chile, from 1918 to 1932 shows no 11-year periodicity as great as 0.5 per cent.

Figure 1 shows the solar variation of recent years and the analysis of it into its component periodicities. In Figure 2 I show by the analysis of the temperature of Clanton, Alabama, that numerous solar cycles shown in Figure 1 make up almost completely the departures from normal temperature at that station. Again, in Figure 3 is shown the 11-month solar cycle in the temperature of Bismarck, N. Dak. After having analyzed temperatures at many stations I find solar cycles obviously present, and composing a large fraction of the total departures from normal. Whatever the theoretical difficulties, I can no longer doubt the importance of solar variation on weather. In short, however extraordinary, it is difficult for one who has fed a giraffe every day to agree with the visitor who on first sight said "There ain't no such animal".

The solar periods that we have recognized in the variations of intensity of the sun's radiation have been announced as 7, 8, 11, 21, 25, 45, and 68 months. But their combined effects, complicated by accidental error make a curve so difficult to analyze that the lengths of any of the periods just given may be inaccurate by as much as 2 per cent. In our analysis of curves of departures from normal temperatures at Clanton, Ala., Washington, D. C., Bismarck, N. Dak., and other stations, we found several other periodicities, as 34, 18, 15, and 13 months. These are subject to similar uncertainty in exact length. We also found certain great features in temperature departures returning in 276 months, or 23 years. I then perceived that, within the degree of uncertainty indicated, all of the periodicities found have their least common multiple in 276 months. As follows:

	a	b	c	d	e	f	g	h
Divisor	2	3	4	6	8	11	13	15
Period	138	92	69	46	34 1-2	25 1-11	21 3-13	18 2-5

	i	j	k	l	m
	18	21	25	34	39
	15 1-3	13 1-7	11 1-25	8 2-17	7 1-3

I also recalled that 23 years, within a similar margin of uncertainty, is the time required according to Dr. George E. Hale, that eminent graduate of Massachusetts Institute of Technology, to complete the magnetic cycle of the sun. In 1908, Hale discovered magnetism in sun spots. He soon found that magnetic polarities are opposite in adjacent spots. Following up the investigation it was disclosed that the order of the two polarities is opposite in the north and south solar hemispheres and that the order continues unchanged through each 11-year sun-spot period, but reverses at the beginning of the next period. Thus it requires two 11-year periods to bring the sun through a full cycle of magnetic changes.

The reader is referred to Figure 4, which gives evidences of the existence of a 23-year period in the deposit of clays during Pleistocene glaciation, 30,000 years ago. Figures 5 and 6 show preliminary attempts at long-range forecasting, based on inspection of 23-year weather cycles preceding the epochs forecasted. The whole research is so very new I must beg indulgence for the crude forecasts. More experience will doubtless lead to better success.[1]

Figure 6 shows the smoothed percentages of normal monthly precipitation found at Nagpur in South Central India from 1856 to 1930. The values are arranged in 23-year cycles, so chosen that the year 1875 begins a cycle so as to fit with most of the lists in "World Weather Records." Lines have been drawn to guide the reader's eye to what seems to me to be homologous features in the four cycles illustrated. I would like to call special attention to the regions 1865-1870, 1888-1893, 1912-1917. In 1865, 1868, and 1870 we find

[1]We have derived our data from "World Weather Records" (Smithsonian Misc. Coll., Vol. 79, 1927), and its continuation to 1930, now in galley proof at the Smithsonian Institution. In order to avoid confusion we have eliminated short-interval fluctuations by taking running 5-month means.

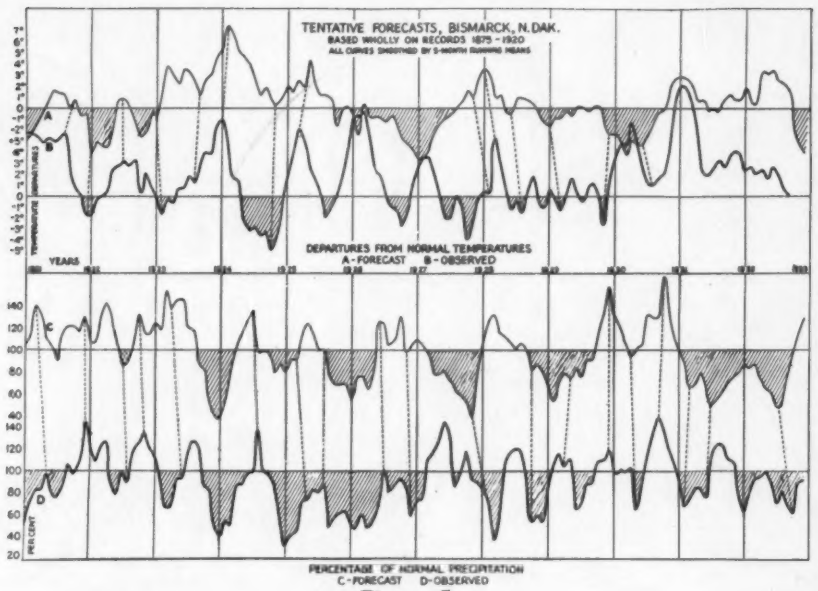

TENTATIVE FORECASTS, BISMARCK, N.DAK.
BASED WHOLLY ON RECORDS 1875 - 1920
ALL CURVES SMOOTHED BY 5-MONTH RUNNING MEANS
DEPARTURES FROM NORMAL TEMPERATURES
A - FORECAST B - OBSERVED
YEARS
PERCENTAGE OF NORMAL PRECIPITATION
C - FORECAST D - OBSERVED

Figure 5.

three pillarlike features of high percentage precipitation bounding two features of subnormal precipitation. Thus there stand out two intervals of three and two years, respectively, as if guarded by these sentinel features, but embracing nearly a score of subordinate feature. The reader's attention is now invited to similar features, 1888-1893, and 1912-1917, in which nearly all the details seem to be recognizable.

The separation between the first and second of these occurrences is almost exactly 23 years, but there is a delay of nearly a year in the appearance of the third. A similar delay marks, however, all of the features from 1899 to 1918, after which the cycle returns approximately to its earlier phase-status. Compare, for illustration, the year 1929 with 1860.

Figure 4 relates to Reeds' publication of the thicknesses of clay varves near Haverstraw, N. Y., laid down in the glacial period and measured independently by Antevs and himself.[2] From these results I have formed 25 consecutive 23-year groups, and have averaged them in groups of five, and also all together. Figure 4 shows the result of this investigation. Owing to a variety of influences, such as warmths of summers, quantity of rainfall, hardness of the soil, and others which would all affect the thickness of the varves, we should not expect close accord in the individual cycles. Yet the five groups, each covering 115 years, show some similarity, and the general mean for 575 years seems to me fairly conclusive that the 23 year period was as influential during Pleistocene glaciation, some 30,000 years ago, as it is now. Eight principal features occur in the general mean, and I am inclined to believe them to indicate that the sun's radiation varied then as now by several periodicities related to 276 months, and that its variations then as now controlled the weather.

In some cases the 23-year cycle has features of high or low values prevailing over the course of several years, and repeated similarly during each cycle. Such cases occur, for example, in the Nagpur precipitation cycles from the twenty-first through to the fifth year, during which seven years the precipitation is subnormal which indicates that it is probable that the subnormal precipitation will be experienced in Central India from 1942 to 1948.

When the attempt is made to forecast weather for coming years in more detail than such general statements as these the embarrassing changes of phase already referred to are encountered. These, though they do not destroy the general sequence of the individual features of the 23-year cycle, produce displacements, sometimes reaching a year, and often several months, in the times of their occurrence. Further research, it may be hoped, will aid in overcoming this difficulty. In order to show the shortcomings of such detailed forecasts if made only with present knowledge, I give in Figure 5 predictions of departures from normal monthly temperatures and percentages of normal monthly precipitation for Bismark, N. Dak. These curves are based solely on records extending from 1875 to 1920, and show the expectation and the event from 1921 to 1932, a forecast and verification covering 12 years. There is considerable similarity (especially from 1921 to 1926 in precipitation) between the forecasts and the events.

It is hardly to be expected that such a *tour de force* as is attempted in Figure 5 could be highly successful. A more modest program is undertaken in Figure 6. Having plotted two complete 23-year cycles extending from 1875 to 1920 inclusive, and in addition plotted one more year, 1921, I pieced on to the last month of 1921 12 months of forecast based on a study of the two preceding cycles. After having drawn this predicted curve I then drew the curve of actual observation for those 12 months. Similarly I proceeded, one year at a time, from 1922 to 1932 inclusive, as shown in Figure 6. Although the fit between forecasted and observed curves is not perfect, the maxima and minima are nearly correctly matched in times, the ranges are usually similar, and the correlation is indeed fairly high.

I propose to try similar verifiable forecasting for many stations and many years. Should these results seem to be favorable in nearly all cases I may even venture a prediction of temperature and precipitation a year in advance for the world. I hope to know before next spring whether or not to attempt this very ambitious program.

[2]See Ann. Rep. Smithsonian Inst. 1930, pp. 295-326.

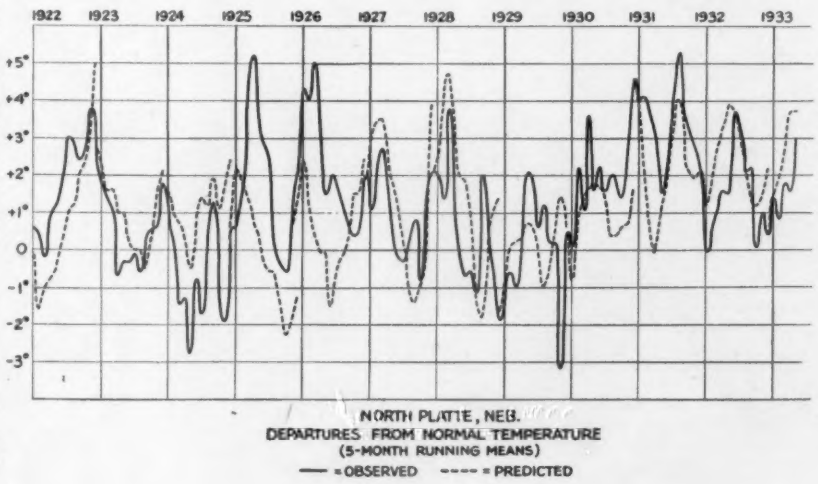


Figure 6.

The Development of ACCOUNTING MACHINES *and Their Uses*

By ARTHUR C. CHUBBUCK
Senior Accountant on the Staff of Patterson, Teele and Dennis.

THE attempts of man to develop mechanical methods of calculation go back to Biblical times according to one writer on the subject. In an article in the December, 1913 issue of *The World's Work* entitled "Leading the Bookkeepers out of Bondage," F. Burnham McLeary very interestingly and amusingly outlined a few of the earliest attempts to devise calculating machines, the forerunners of the modern accounting machines. Apparently the earliest attempt was occasioned by Noah have some trouble with his inventories, for Mr. McLeary says,

"The flood was a great landmark —historically speaking—in the development of the calculators. Shem, it appears, was rather put out at the crude tally kept on the animals in the ark. Accordingly, he and his children—the yellow people of Asia —contrived some queer little rigamagigs and distributed them among the Mongolians. There were only a few of these tally boards to start with, but they added and multiplied like Jehu. At the ripe old age of 624 Shem breathed a long sigh of satisfaction and expired. He had introduced the abacus into every Chinese laundry from Kokomo to Calcutta."

International Business Machines Corp.

International "Hollerith" alphabetical tabulating machine.

It may be assumed that with this glorious achievement, progress in the development of calculating machines rested. The next attempt, centuries after, in the year 950 A.D. or thereabouts, apparently was made by one Gerbert, better known perhaps as Pope Silvester II, who, before being so elevated by the Roman Catholic Church, is credited with having introduced the Arabic numerals into Christian Europe, and with having tried unsuccessfully to make these numerals do tricks through the media of several different calculating devices.

Shortly after the discouraging efforts of Gerbert, another churchman, a priest by the name of Magnus, appears in the role of a calculating machine manufacturer. Of this historical incident Mr. McLeary says:

"About the year 1000 a wily priest named Magnus tamed the numerals and drove them in among a lot of cog wheels. He then enclosed the whole contrivance in a big brass cranium and added, eyes, nose, mouth, and two ears, all of beaten brass. Once in a while, if properly humored, the arabics would do sums for him. On such occasions the answer would come trooping out, just where the eye teeth should have been. The other priests thought there were devils or wizards inside, and like a fool he let them think so. Whereupon they fell to with sticks and stones and smashed his graven image into smithereens."

Developments of Pascal, Leibnitz and Others:

Apparently, the next step of importance in the evolution of calculating machines occurred in connection with the works of two noted scientists of the seventeenth century, Pascal and Leibnitz.

To Blaise Pascal is credited the invention in 1642 of the first "addition machine", to be followed shortly thereafter in 1671 by the development by Leibnitz of an "addition machine modified to facilitate multiplication."

In the mechanical principles of these machines and the subsequent developments of Johann Helfrich von Mullen (1786), Charles Babbage (1822 and 1834), Stettuer (1882), Mayer (1887), Leon Bolles (1888), Felt (1888), Burroughs (1889) and Steiger (1894), there appeared a progressively increasing resemblance to the calculating and accounting machines of the present day.

First Tabulating Machine:

It is also interesting to note that Charles Babbage, among his other contributions to science, conceived in 1834 the idea of an "analytical engine" to be operated by the aid of cards into which holes had been punched and through which levers might drop. This is the first instance which has come to the writer's attention of any mention of calculating machines operating on the punched card principle, as exemplified by the modern tabulating machines.

Because of the limitations of space, it is necessary to forego the interesting details connected with the process of mechanical refinement and the broadening of the scope of machine application to accounting which has finally resulted in those machines which are now quite universally recognized as being very necessary tools of the modern business office, regardless of its size.

Importance of Study of Problem of Application:

With the constantly increasing scope of application of accounting machines generally, particular attention by the manufacturers of such machines has been directed to the attainment of maximum productivity with respect to each specific accounting task which such machines may undertake, through the development of special devices and special "hook-ups", which correspond very closely in purpose to the jigs and special tools of the machine shop.

As an illustration of the extent of this development, a sales executive of one of the larger manufacturers of accounting and business machines stated recently that in the case of the accounting machines sold by the company which he represents, such combinations of basic machines and special "hook-ups" numbered approximately one hundred and thirty. This number does not indicate the limit of the number of separate

(Continued on page 161)

The Contribution of the GYROSCOPE *to Safety in the Air*

By ATHELSTAN P. SPILHAUS G

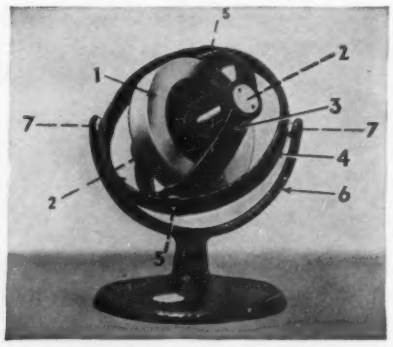


Figure 1 — Demonstration model gyroscope, showing the direction of the precession resulting from a downward pressure of the finger.

Illustrations courtesy Sperry Gyroscope Co.

THE gyroscopic principle has been employed in many and various fields and in recent years one of its most striking applications is undoubtedly its incorporation in certain aircraft instruments.

When the airplane pilot is deprived of visual reference with which to orientate his machine, he is helpless for the liquid level in his aural canals and the deep muscle sense are merely inertial indications and are no more able to distinguish between gravity and any other acceleration than is the simple pendulum. Thus, in a correctly banked turn the pilot will still have the sensation of the resultant acceleration acting perpendicularly downwards to the plane upon which he is seated and he is therefore unable through these senses, other than visual, to know whether he is in a spin or in level flight.

The gyroscope, however, provides a means of obtaining artificial references in the airplane itself which may be used when external visible reference is obscured. The wheel or rotor of the gyroscope spinning at a high speed represents a means of concentrating angular momentum about one axis while the momenta about the two other mutually perpendicular axes is kept to a minimum. This angular momentum has a direction in space which can only be altered by the application of a torque. Thus, if the gyro is suspended in such a manner that no torque can be communicated to it from outside except about its axis of spin, it will maintain a fixed direction in space and thus would form the necessary reference.

In practice, friction renders it impossible to construct a suspension which exerts no torque about the axes and, indeed, this proved to be such a serious drawback at first that the earliest gyroscopic aircraft instrument to give widespread satisfaction, the Turn Indicator, depended on the "precession" of the axis of spin when a torque is applied. Precession is simply the rotation of the axis of spin about any axis at right angles to it. In general, if a torque is applied about any axis not coincident with that of spin, precession will result about a line perpendicular to the plane containing the spin and torque axes.

This seemingly peculiar contrariness of the gyro axis to tilt at right angles to the plane in which the torque is applied may be explained non-mathematically by simply considering the following conception. In nature the action resulting from a cause will proceed in such a manner as to tend to allow that cause to exhaust itself. Thus, in the gyroscope when a torque is applied, the axis of spin will precess by the shortest route into a position coincident in direction and sense with the axis of torque.

In the Turn Indicator this property of precession was utilized by suspending the gyro wheel with its spindle parallel to the wing span of the airplane in a single gimbal system whose bearings are in a line parallel to the length of the airplane. The airplane itself then represents the second gimbal of the system and any turn of the airplane about the third axis, perpendicular to the other two, causes a precession of the gyro axis towards the axis of turn. A spring retains the gyro spindle in its normal position parallel to the wing span in straight flight, but in a turn the amount of departure from this position, *i.e.* the amount of extension of the spring, is proportional to the rate of turn and the sense in which this departure takes place gives the direction of turn. A suitable pointer arrangement transmits to the pilot the information as to the direction and rate of turn. A better name for this instrument would be the Rate of Turn Indicator.

A second instrument, the Artificial Horizon, shown in Fig. 2, depends primarily on the tendency of the gyro axis to remain fixed in direction when it is universally mounted. But, as has been pointed out, the small frictional torques exerted by the bearings in the gimbal mounting will cause a slow deviation. Remembering that the precession takes place in a plane at right angles to the plane of the applied torque, the air jet reaction method of keeping the gyro axis vertical, which is chosen as the initial position, is extremely ingenious and simple. The air after impinging on the periphery of the rotor, to impart to it

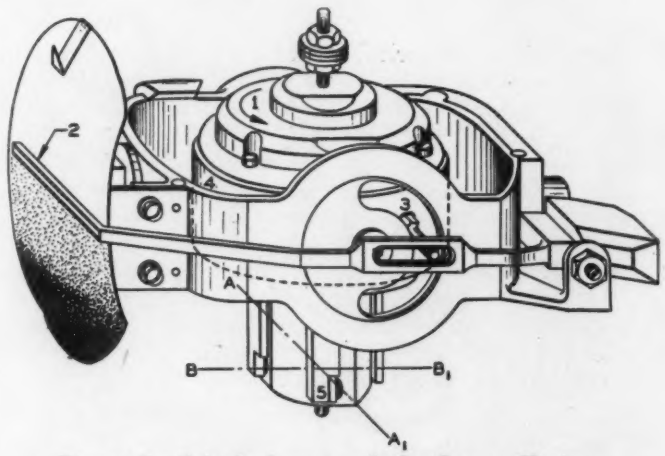


Figure 2—Principal parts of the Sperry Horizon.

the necessary spin, is exhausted through two jet systems mutually perpendicular and perpendicular to the gyro axis. Each jet system consists of a pair of opposite jets which are differently controlled by pendulous vanes. This means that, if the axis tilts in the plane AA_1 toward A_1, the differential reaction to the jets will act as B (for the opening at B will be increased while B_1 is decreased) and this reaction will cause the axis to precess in the plane AA_1 back to a position where parallelism with the pendulous vanes will reduce the differential reaction to zero.

The Artificial Horizon controlled in this manner behaves like a long pendulum which in a turn has such a long period that it has not time to deviate very appreciably from the vertical before the turn is completed. The reference to the vertical is then transmitted to the pilot by means of a bar, representing the horizon which moves relatively to a small airplane which is fixed on the dial of the instrument and thus the indications of lateral and longitudinal position are shown in a perfectly natural manner to the pilot. In normal flight the average resultant acceleration coincides with the vertical.

The third of the commonly used instruments, the Directional Gyro, is designed primarily to overcome certain inherent disadvantages of the magnetic compass. The principal of these is the so-called "Northerly turning error". This error, which has the effect of showing the opposite sense of direction when the airplane is turning from a northerly course, is caused by the centrifugal force acting on the "dip" counterbalance weight which is placed, for operation in the northern hemisphere, on the south seeking end of the magnet. In the southern hemisphere the reverse is true and balance weight has to be added to the north seeking pole and produces a corresponding "Southerly turning error". The Directional Gyro is, of course, not subject to this error, being simply the nearest approach to a free gyro that precision of manufacture can attain.

Minute frictional torques which still remain, however, cause a slow wandering from the fixed position in space and the Directional Gyro must be periodically referred and reset to the reading of the magnetic compass in straight flight. In the present instrument as most generally used this resetting is accomplished by hand, but it was the logical step to arrange the Directional Gyro so that it would be controlled automatically by the Magnetic Field. In the very near future the Directional Gyro controlled by a magnetic com-

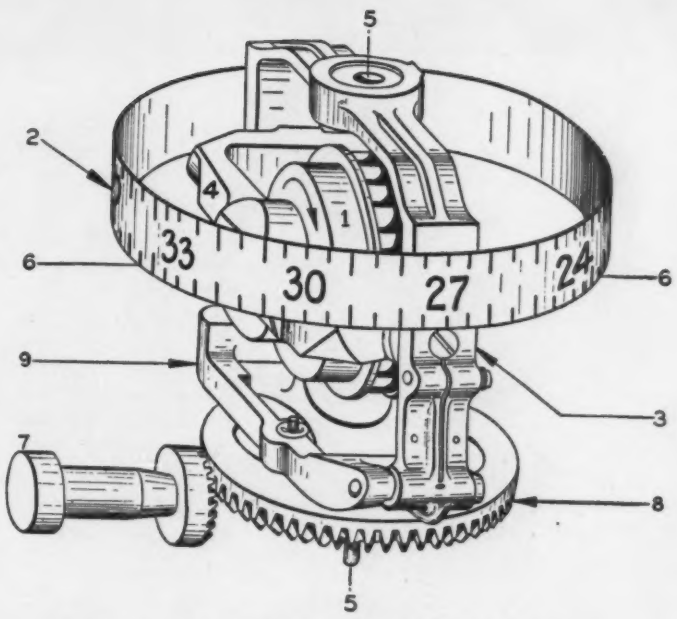


Figure 3—Principal parts of the Directional Gyro.

pass will be brought out. Thus in a turn the Gyroscopic directive force will predominate but will become subservient to the magnetic compass card in straight flight.

Considering this latter magnetically controlled gyro compass and the Artificial Horizon previously explained, it becomes evident that the gyroscopic contribution is to introduce sufficient lag in the instruments to enable the temporary obscuring effects, which enter due to the deviations of the airplane from straight flight, to be rendered negligible and to preserve the two predominating references, namely the magnetic field and the gravitational acceleration.

In the automatic pilot for airplanes, shown diagramatically in Figure 4, no further principle is involved. These two instruments, the Artificial Horizon and the Directional Gyro simply are arranged with an air relaying mechanism which sets in motion hydraulic cylinders which in turn operate the airplane control surface to apply the corrective action and restore the airplane to the neutral position. The neutral position is controllable by adjusting knobs and may be set for varying amounts of climb or for level flight, for any particular direction or for a certain rate of turn; and, furthermore, the inclusion of a pressure element permits sustained flight at any particular pressure altitude if desired. In the Sperry Pilot the whole automatic mechanism may be switched out at any time.

The tremendous usefulness of these gyroscopic aircraft instruments in promoting safe flying in bad weather conditions and in relieving the human pilot of fatigue has been admirably demonstrated in Mr. Post's round-the-world flight. Their inclusion in the form of individual instruments or as the "brain" of the Automatic Pilot is becoming almost universal in airplanes today and this is perhaps the best evidence of the magnitude of the advances in scheduled flying made possible by this gyroscopic application.

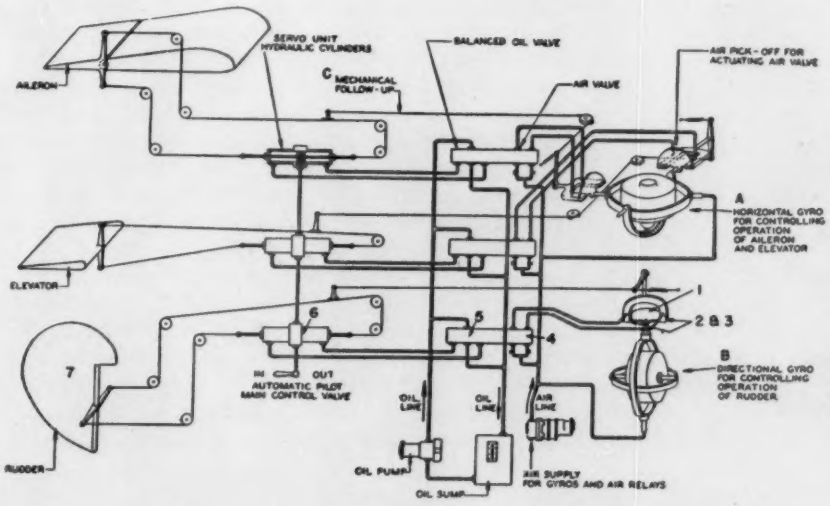


Figure 4—Diagrammatic drawing of the Sperry Pilot.

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EDITORIALS

ENGINEERING THE RAILROADS

THE problems of our immense railway system have been before the public for a generation. These troubles were at first political, involving regulative and even punitive action by legislative bodies presumably acting in the interest of shippers. Later, the railway's troubles became financial. The combination of rate regulation, labor regulation, and taxation impaired earnings and credit. Now all these troubles are becoming acute with the development of competition to take away important portions of the railway's normal volume of business.

The private automobile seems permanently to have secured the lion's share of shorthaul passenger traffic, the bus also takes a little, and the airplane is eating into the long-haul Pullman traffic. Motor trucks handle a good part of the freight in volume less than carload lots.

As a result, branch lines paralleled by highways are a liability to any railroad. The best that can be done with them is to abandon service. Passenger business between main line stations, less than 150 miles apart, has gone to the automobile. The cause has been working openly for twenty years—progress in automotive engineering.

The automotive engineer and his colleague, the aeronautical engineer, have developed, around the internal combustion engine, light stable vehicles built of alloy steel and aluminum and mounted on rubber, capable of speeds surpassing anything conventional railway practice can contemplate without a shudder. These speeds are obtained with superior silence, comfort, and privacy. Small flexible units on frequent schedules make the time table an antiquity.

It seems obvious that the railroads will be forced to adapt the results of automotive engineering in their own rights of way. Automotive trains are now being tried by the principal railroads. They promise sustained speeds double that of existing trains at half the cost, treble the frequency of departure, and with greater comfort and safety than highway vehicles. This development appears directed first at main line passenger traffic and will require diversion of heavy and slow freight to other rails. A complete revision of the railway map is implied.

The re-equipment of the railroads to bring back the passengers will be one of the biggest jobs of the engineering profession for the next ten years. The money to accomplish the work may not be in sight, but, when the necessity is realized, it will certainly be found, either from private capital seeking a return, or from public credit seeking to meet a social demand.

JEROME C. HUNSAKER,
Head of the Dept. of Mechanical Eng.

EDUCATION AND THE DEPRESSION

EDUCATION in America is facing the most serious crisis in its history according to Dr. George Frederick Zook, U. S. Commissioner of Education. Thousands of public schools, especially in the South and West, have been unable to open at all this term because of depleted municipal and county treasuries. Hundreds of thousands of teachers are idle while a large number have been unpaid for months; classes in all public schools are crowded to or beyond capacity. The length of the school year, always too short in many rural sections of the country, has been reduced in many localities to the extent that the quality of scholarship must be severely impaired.

This general demoralization of our public educational system is one of the many effects of the depression that will be felt most keenly in future years. It is obvious that the future cultural and intellectual development of America is vitally dependent upon the education of our youth today. It is unfortunate that the younger generation should be deprived of the opportunity for intellectual advancement by the mistakes of their elders. The general standard of public education in America has always been lower than that in many European countries. We can little afford such retrogression.

In its attack upon the depression and its ill effects, the federal government is lending billions of dollars both for direct relief and for the reviving of industry. It appears that some of this money loaned to the more destitute of our school systems would be a better investment toward the future welfare of the nation.

WOODEN LEG OR CRUTCH

WITH the low ebb in construction work, architects and engineers are perforce greatly interested in projects financed by the Federal Government. Our Government and our people, in common with the other nations of the world, are struggling against the demoralization of a business catastrophe; individuals must hesitate to further rock the boat. However, we still hold the traditions of a free people, and temperate expressions of opinion are not forbidden.

In normal times, private capital has been attracted to building projects in generous proportions. The steady and rapid growth of most American cities has made real estate ownership or mortgage investment an attractive and generally secure employment for capital.

The rapidly mounting taxation of real estate for the past decade, and the tremendous shrinkage in demand since the depression, have made real property ownership and mortgage an extremely unprofitable and hazardous field. Furthermore, the state of the bond market indicates the general skepticism and hesitancy in all capital investment as distinct from speculation. The revival of building construction through the investment of private funds seems discouragingly far off. At first reaction the large scale investment of Government funds in the construction field seems, therefore, like a life saver to this great industry.

The experiences of the past several months, during which the Government has attempted to allot P. W. A. funds, has, however, confirmed the fears of many as to the feasibility and desirability of attempting widespread revival through such means. The cumbersome movements of the Government bureaus, departments, boards, advisors, technicians and whatnots, the appalling, deadening, effect of waiting hat-in-hand on Washington, and the contemplation of the inevitable reckoning in moneys misspent and enormous debts contracted, make a conservatively-minded person, even though a direct benefactor of the scattered riches, experience chills along the spine.

With the mountainous debt accumulation of such expenditures to be taken care of, and with countless communities burdened with works of all kinds beyond their real needs and abilities to carry, will the ultimate recovery of private initiative and investment not be greatly postponed? Can the planning of bureaus, boards, administrators etc., actually produce works as beneficial to our people as can individual initiative and courage, fired by the hope of profitable return?

The present large-scale entry of the Government into the construction field should be treated simply as a crutch to tide over the lameness of our industry; its continuance should be brief and limited. To use the crutch too long will delay indefinitely the time when the industry can stand on its own feet and walk alone.

N. A. RICHARDS,
Vice-President,
Purdy & Henderson Company.

CHANGES

DURING the past eight issues the TECH ENGINEERING NEWS has purposely followed a policy of offering articles of national interest and widespread appeal at the sacrifice of the purely engineering or scientific articles in former years. Although it has been our pleasure and privilege to publish articles by such men as Richard P. Whitney, Charles Abbott, and others of national renown, nevertheless, comments and criticisms we have received from our readers show us clearly that there is by no means only one side to the question. We have heard and weighed the various comments on this change of policy.

With this issue we retrace our steps part way, offering, for the most part, articles more highly technical than have been seen in the magazine during the past year. We do so, not because we feel we have made a mistake, but because we desire to leave the incoming Board in a position from which it will be easier either to return to our policy or to go back to that which we discarded. Any further comments from our readers on this moot question will be greatly appreciated by the new Board and will serve to aid them in determining their policy for the coming volume.

Another innovation with this number is the change in the month of issue, which was brought about by our desire at this time to start a public newsstand circulation. Although the present number is called the February issue, publication dates remain unchanged, and henceforth each issue will be dated one month in advance.

The last, but by far the most important of the changes in the TECH ENGINEERING NEWS is the change in management which occurs at this time.

The Managing Board of Volume XV will be Henry J. Ogorzaly '35, General Manager; Zay B. Curtis, Jr. '35, Editor-in-Chief; James D. Parker '35, Business Manager, on the Senior Board. Comprising the Junior Board will be Brenton W. Lowe '36 and David J. Gildea '36, Associate Editors; Norman G. Bull '36, Managing Editor; Scott C. Rethorst '36, Advertising Manager; Dorian Shainin '36, Treasurer; and Robert E. Williams Jr. '36, Circulation Manager.

To this new Board the outgoing Managing Board of Volume XIV wishes every success.

ENGINEERING DIGEST

TELEVISION ADVANCES

THE attention of radio experts throughout the world was attracted by Dr. Vladimir K. Zworykin, research engineer of the R.C.A.-Victor Company, when he recently announced his invention of a television pick-up device known as the iconoscope. In disclosing some details of his device before the annual convention of the Institute of Radio Engineers in Chicago last summer, Dr. Zworykin explained that the iconoscope duplicated the action of the human eye with parts that correspond to the human retina and nerves.

The duplication is accomplished by a vacuum device with a unique photo-sensitive surface scanned by a cathode-ray beam, which serves as a type of inertialess commutator. In its application to television, Dr. Zwarykin states, the iconoscope replaces mechanical scanning equipment and several stages of amplification. The whole system is electrical without a single moving part, thus permitting a very high output from the device. The entire apparatus consists of the cathode-ray camera mounted on a tripod and the separate amplifier cabinets.

An integral part of the iconoscope consists of 3,000,000 tiny microscopic photo-cells, held in a mica sheet measuring 4 by 5 inches, and enclosed in a vacuum tube sixteen inches long, with a bulb eight inches in diameter.

The light impulses of the television subject or scene are taken for the iconoscope through a common cinema lens, then transformed, in the cathode-ray tube by means of the electron beam playing on the 3,000,000 cells, into electrical energy for the radio transmitter. In turn, this energy is picked up by the cathode-ray receiving tube and transformed back into light energy, thus yielding a reproduction of the televised image.

In contrast to ordinary television systems in which every point of the picture acts on a photo-electric cell in the order of 1,500,000th part of a second, the inventor points out that in the iconoscope every point of the picture acts on a photoelectric cell all the time, and there is provision in the structure which collects the energy of the light figuratively to "memorize" it, and then transmit it twenty-four times a second.

Thus, he explains, it can be seen that the amount of energy stored in the new photo-cell, as compared with the old system, is the ratio of one to twenty-four as against one to 1,500,000, a "memory" 70,000 times greater than the output from the picture possible with the disc scanner method under identical conditions. (*Radio News*, vol. 15, no. 4, October, 1933, pp. 214-215, 7 figs.)—M.S.C.

ELECTRIC WELDING UNDER WATER

THAT electric arc welding may be accomplished under water is not a widely known fact. Just recently, however, it has been found that arc welds are not only possible when completely immersed but are of a quality which actually equals that of arc welds produced in air.

There seems to be only one main difficulty involved in under-water welding. When an arc is struck, a bubble of vapor is formed about the arc, and dense clouds of incandescent gases and steam are evolved. As a result the operator can not see the arc, and as a successful weld depends on a very steady depositing of the metal, the operator must see what he is doing.

To overcome this obstacle the idea of a shield for the arc was brought forth. Attempts made with the bare-wire electrodes covered with tape or paper proved fairly successful, and it was believed that if a shield could be found such that it would give a uniform burning as the electrode melted away, the problem would be solved. In the last few years, different types of covered electrodes have been produced, and a number of these were tried in under-water welding. Two types were found to be practical although even these had disadvantages. One with a covering of some organic material created clouds of black smoke which required a constant flow of fresh water in order to be carried away; while the other with a coating of a metallic oxide left a heavy slag on the weld, making a mass to be cleared away before a second bead might be laid.

The actual technique involved in under-water welding is quite interesting. In addition to observing the precautions and essentials familiar to welding in air, the operator must follow a unique system in applying his electrode. He must move it with the idea of balancing it over the arc as though the arc were an inflated ball to be held under the water. Also to determine whether he has the right arc length, he must make use of the sound evolved. If he has the correct length, a steady low rumble will be emitted, but if he has not the correct length, sputterings and small explosions will occur.

In comparing the quality of the results of air and under-water welding, all kinds of tension and free bend tests reveal them to be practically equal in every respect. Experiments were made in which salt water was used instead of tap water, and it was found that the quality of these welds was still equal to the quality of those performed in air. In the case of the salt water, however, it was found that there was a considerable leakage of current before the arc was struck unless all possible area of conducting surface was insulated.

In considering the importance of under-water arc welding, it may be seen that in experimental work where it is desired to limit the heat penetration from the weld or to avoid distortion of the parent material from excessive heating, this method has great value. Also various uses of practical value may be found in connection with marine salvage and construction. (*Journal of the American Welding Society*), vol. 12, no. 10, October, 1933, pp. 4-9, 8 figs.)—J.C.W.

MORE USES FOR COPPER

A NEW process for electrodepositing copper has been recently developed which makes it commercially available in extremely light, thin sheets. These sheets weigh as little as one ounce per square foot, are as wide as thirty inches, and come in rolls of optional length and uniform thickness.

The copper is deposited on a large lead-faced drum by an electric current much stronger than that used

in ordinary copper plating. This lead drum slowly revolves in the plating solution and the copper which has been deposited passes from this plating bath to a cleansing bath. Sheets up to sixteen ounces in weight can be made by passing the copper over a series of rolls through long tanks in which copper electrodes are suspended to replenish the plating solution.

This light, paper-weight copper has many commercial possibilities. At the present time, automobile engineers are experimenting with copper weighing one and a half ounces per square foot as a topping for closed cars. It has valuable applications when bonded with textiles, paper, fiber, felt, composition board, and also with other metals.

Thin sheet copper is also being used on certain types of recording instruments in place of paper, since changes in humidity have practically no effect on its dimensions and consequently makes it more accurate than paper for delicate recording. It is being used for novelty greeting cards and as bindings for books subject to severe usage.

Electrodeposited copper has a lower tensile strength than rolled copper and a somewhat less dense structure. This material is very weather resisting and the thin sheets dissipate heat so readily that allowance for expansion and contraction is unnecessary. (*Scientific American*), vol. 149, no. 5, November, 1933, p. 225)—R.B.E.

AIR CONDITIONING COMPRESSORS

UNTIL the last few years compressors have been driven almost entirely by means of belts and gears, at speeds of only 100 to 500 R.P.M. Today reciprocating compressors are being operated with entire success at two or three times this speed, with appreciable advantages in performance.

Electric refrigeration and air conditioning contributed largely to the change, with the result that these modern compressors provide a number of outstanding features, such as light weight, quietness, freedom from vibration and high efficiency.

The advantage of light weight and small over-all dimensions are obvious, especially in refrigeration and air-conditioning applications. Other benefits, not so apparent but none the less real, are almost equally important. Compactness is obtained not only because of the elimination of bulky speed-reducing mechanism but also because the same displacement per unit of time is achieved with smaller cylinders as a result of the higher operating speed. Consequently bearings, crankshaft and all other parts of the compressor become smaller and cheaper. Compactness, therefore, means less expensive replacement parts and lower first cost, or higher quality at the same cost.

Even a slight vibration produced by a belt or gear drive makes it difficult to obtain an absolutely gas-tight joint with the conventional bellows-type shaft seal used on refrigerant compressors. With a direct-connected compressor this vibration does not exist. It was once thought that high speeds would bring other troubles with compressor shaft seals on which the bearing face was 1-7/8 inches in diameter, no wear could be detected when the seals were dismantled after over a thousand hours continuous running without leakage at a speed of 1750 R.P.M. These results have been duplicated on actual installations for railway car air conditioning. These tests are being continued to attempt to determine whether there is any limit to the life of a properly designed seal.

Mechanical and volumetric efficiencies of direct-driven reciprocating compressors compare favorably with efficiencies obtained with old-style slow-speed compressors. High speed compressors must be designed with large ports and valves so that the losses due to the high velocities of the gas will not be serious. Volumetric efficiencies well above 80 per cent have been secured consistently with compressors running at 1150 R.P.M.

With the number of applications of compressors increasing rapidly, operating speeds which are now considered excessive will probably within the next few years be regarded as quite conservative just as are the speeds of steam turbines and automobile engines of ten years ago when compared with those of modern machines. (*Westinghouse Technical Press Service,* report no. A-62267-A, 1 fig.)

TRAFFIC CONTROL

HOW many people regard traffic lights as obstacles placed along the route to lend zest to the monotony of automobile travel? Perhaps you thought that they were conveniently located at intersections by a benevolent government to make your trip downtown a fascinating game of scurrying through changing lights, rapid acceleration to display the pick-up of your car, and squealing stops. At any rate there are probably none of us who have not cursed and fretted while we waited for the inexorable red to flash to green or the white glove of the traffic officer to be lowered.

Assuming that we have all felt at some time or other that traffic would flow more smoothly at intersections if all "cops" were dead and traffic lights were confined to railroads, it would be well to present a few statistics of interest.

Normal street traffic (non-rush hour) of around 2,000 vehicles per hour crossed a Washington, D. C., street intersection with least delay when under no control, and two hours of peak traffic caused as much delay as eight hours of normal traffic. These conclusions were among the results of a traffic study made by the Bureau of Public Roads as reported by E. H. Holmes, assistant highway economist, to the annual meeting of the Highway Research Board of the National Research Council which was held in December, 1933, in Washington, D.C.

Tests of traffic flow at 17th Street and Constitution Avenue, Washington, D.C., were made to analyze the delay caused to moderately heavy flow of traffic by different control methods. Delays were greater under all systems of control than when there was no control; and of the various control systems, officer control caused the least delay, followed in this respect by the shortest fixed-time control and the traffic-actuated control.

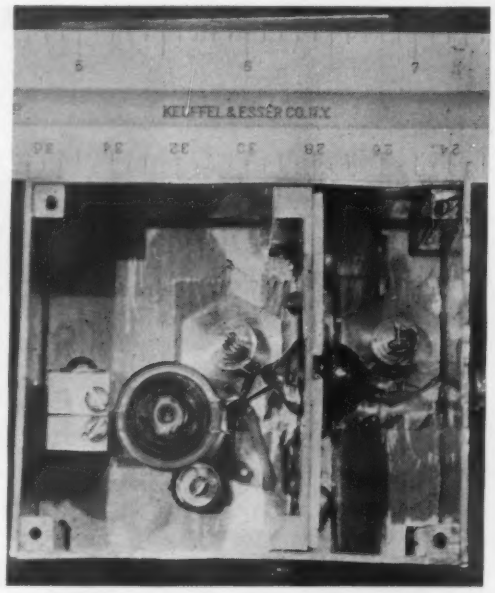
The traffic engineers discovered that under the fixed-time control, a very marked increase in delay followed the lengthening of the time between traffic direction changes. The flexible control methods (officer and traffic-actuated) were as effective as the most efficient fixed-time control. During a ten-hour day (8 A.M. to 6 P.M.) the two hours of peak traffic that occurred caused as much delay as the remaining eight hours.

Rush hour traffic was not considered, according to the report, because it was desired to study the various control methods under constant traffic volume. It was found that the volume changed so rapidly in rush hours that the flow could not be studied for time losses. (U.S. Department of Agriculture, report no. 1284-34, December, 1933.)

RESEARCH IN REVIEW

COURSE II — Mechanical Engineering

SINCE the introduction of interferometric methods in the Testing Materials Laboratory by Mr. R. W. Vose two years ago, the wave length of light has been found a very convenient unit and means of measurement in several strain and motion problems. The green line of the mercury spectrum (wave length 5461 A°) was first used as a standard of length in a specially designed interferometer for the calibration of the delicate Huggenberger strain gages, which read to a hundred-thousandth of an inch. Through the use of this apparatus a recent investigation of the behavior of these Huggenberger gages under varying conditions of use has resulted in a segregation and evaluation of certain systematic variations heretofore classed as "inaccuracies", and added materially to the confidence placed in their indications. Since the phenomenon of interference takes place without physical contact between the elements of the interferometer, it can be used in situations where the pressure of a micrometer screw contact or the friction of a magnifying lever would obscure the minute motions to be measured. Very simple instruments on this principle have been used for determining the lateral strains in materials, particularly for finding "Poison's Ratio" and for solving strain distribution problems in the photo-elastic method of analysis (see Mr. Maeser's article on photoelasticity in the April, 1933 issue of the T.E.N.).



Electronics.

Research in ultra-short wave receivers has been carried on by an outstanding manufacturer. This picture shows one of these receivers with a comparative scale of inches. The tubes employed were described in the December issue.

The Department of Mechanical Engineering is taking a forward step in its starting a course in welding. Heretofore the welding laboratory has been used only in conjunction with other courses and never for a separate course devoted entirely to welding. The course, which will probably be started next term, has as its primary object the familiarization of the students with welding engineering and the applications of welding, and the course is not intended to produce expert welders. As work progresses pioneer research in the line of welding will be carried on by students and the staff.

COURSE V — Chemistry

PROFESSOR UNDERWOOD and his students are studying compounds of the phthalein type with the purpose of developing a more precise relationship between color and structure in this series and the elucidation of the theory of indicators. Recent work, of a different nature, has led to the preparation of satisfactory derivatives for the identification of alkyl and related chlorides and of aromatic hydrocarbons. An investigation of the bromination of hydroxy-cinnamic acids has advanced the knowledge of the competitive reactivity of the functional groups in this series.

Automatic control of pressure during vacuum distillation of organic compounds has long been desired by organic chemists. Such regulations is now effected by a simple thermionic control devised by Professor Huntress and Doctor E. B. Hershberg during some studies on the identification of organic halogen compounds.

At present, Professor Huntress and his students are studying the preparation and chemiluminescence of various organic compounds with a view to determining the mechanism of the reaction and thus the relation between the chemical structure and the nature and the quantity of the light produced.

Doctor Milas has been engaged for some time in the study of the mechanism of auto-oxidation reactions, and the formation and decomposition of organic peroxides. Another problem which Dr. Milas has been studying during the past several years is the synthesis and elucidation of the chemistry of vitamins A and D. A new method for the production of the latter has already been developed. In collaboration with students he is now actively engaged in an attempt to synthesize vitamin A or some of its derivatives.

Doctor George Thomas is giving particular attention to the behavior of hydrocarbons when heated slightly above the initial decomposition temperature. It has been found in this laboratory, that under such conditions, only one definite carbon-carbon bond in the aliphatic hydrocarbon chain is broken. This is a new and novel result since the prevailing view is that *all* the bonds in an aliphatic hydrocarbon are liable.

In cooperation with Professor Proctor of the Biology Department, a study is being made of the action of a certain type of mold on hydrocarbons and alcohols with the object in view of finding the mechanism of the reactions which take place.

An investigation of the relation between the valence angle of the oxygen bonds in ethers and the stability of these ethers has been started.

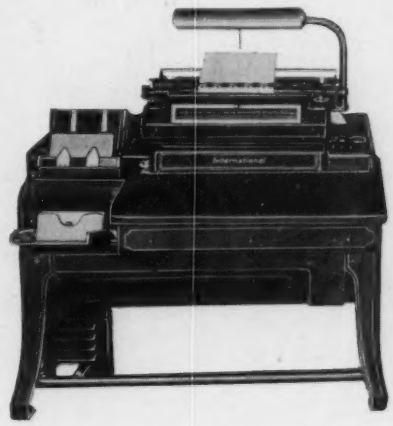
Doctor Ashdown, with students, is engaged in the preparation and determination of physical constants, including absorption spectra, of some highly purified cyclic hydrocarbons and their isomeric unsaturated relatives, with a view to the application of these data to a more precise study of the molecular structure of these compounds and the genetic relationships existing between them.

(*Continued from page 153*)

accounting jobs that could be undertaken, inasmuch as any one of the one hundred and thirty special "hook-ups" could, through minor adjustments, undertake many jobs. This statement means rather that some phases of the particular problem for which the machine was intended was of sufficient importance, from an operating cost standpoint, to justify the special "hook-up".

Equally vigorous and effective, considered generally, have been the efforts of certain other manufacturers of accounting machines to produce machines of broad application and high productive efficiency, although all such manufacturers may not have attached equal importance to, or have been equally successful in, the development of mechanical ability to perform each of all the important and necessary accounting operations.

The matter of selection of accounting machines, therefore, must be made with specific consideration for the detailed nature of the work to be undertaken and if the available maximum of productivity and quality is to be obtained at a fair cost, such selection involves as careful and detailed a study of the specific problem as is required in the selection of a machine for the modern factory.



Underwood Elliott Fisher.

Underwood standard bookkeeping machine.

Types of Modern Accounting Machines

Modern accounting machines may be classified broadly as follows:

1. Calculating machines:
   - (a) Key operated type
   - (b) Rotary type
2. Adding and Subtracting machines
3. Bookkeeping machines
4. Tabulating machines

In the following paragraphs will be found a brief description of the better known accounting machines with as much reference to the uses of such machines as space permits.

Calculating Machines—Key Operated Type:

Probably the two best known examples of key operated calculating machines are the Comptometer and the Burroughs Calculator. Both machines are non-listing, *i.e.* no printed list of the details of a calculation is produced. In all models of the Comptometer, calculations are accomplished mechanically by depressing the keys, while in the case of the Burroughs, there are available both electrically and mechanically actuated models, each operated, however, by depressing the keys.

Both the Comptometer and the Burroughs Calculator are fast in operation, are easily portable, and have broad possibilities of application, particularly in calculations involving addition and multiplication. These machines are widely used in connection with sales analysis, inventory calculation, payroll calculation, general cost accounting and other similar work.

A comparatively recent improvement in the field of key driven calculating machines has been the introduction of the "peg board," a device which, by providing the means for holding a primary accumulation of figures in an easily legible position, simplifies greatly the progressive accumulation of such figures, such as, for example, accumulating from original sales invoices, daily totals of sales according to departments and "recapping" such daily totals in order to obtain weekly and monthly totals.

The most recent improvement has been the addition of a grand total dial to which totals may be transferred as accumulated, thus further simplifying the process of recapitulation.

Calculating Machines—Rotary Type:

A major difference between the key driven type of calculating machines and the rotary type of such machines is that, in the key driven type, depressing the keys actuates the mechanism which performs the desired calculation while in the rotary type, depressing the keys merely sets up a combination of figures which is used then in a calculation effected by turning a crank or closing the circuit of an electric motor which "turns the crank." The rotary type like the key driven type is non-listing. It is available equipped with automatic division and multiplication so that upon the introduction of the two factors of the calculation into the machine the calculation is performed automatically.

An improvement in this type of calculating machine, consisting of an added accumulator dial and other devices which broaden considerably the possibilities of application, has been introduced recently by one manufacturer.

Adding and Subtracting Machines:

Machines embraced by this classification and of current production are almost exclusively of the listing type and are used generally where a printed list

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of the figures comprising the total is of greater importance than speed in producing the total. These machines may also be used for multiplication.

Certain models of these machines will add or subtract, as desired, and in cases where the total of the negative figures exceeds the total of the positive figures, will print the net total as a positive "credit" balance. Other models will also list and add several columns of figures and furnish a grand total. Upon making slight changes in the machines discussed briefly in this group, such as substituting a moveable carriage, posting machines are obtained, which will be discussed under the general caption of "bookkeeping machines."

Typical uses for machines comprising this group are listing sales, taking trial balances, and balancing hand posted ledger accounts.

One of the latest additions to this group is a machine of the listing type which, weighing but eleven pounds, may be carried about with ease or kept in a desk drawer.

Bookkeeping Machines:

This class of accounting machines has evolved rapidly from the typewriter with an accumulator attached and from the adding machine with a listing device, to the present machines, each with distinctive mechanical features, according to the manufacturer's interpretation of the importance of certain bookkeeping operations, each with the primary purpose in view of making one posting operation perform as much in the bookkeeping program as is practically possible.

Of the two general types of bookkeeping machines mentioned above, the typewriter type affords a greater possibility of descriptive detail and a much wider range of columnar accumulations. The adding machine type, in which a limited amount of descriptive detail is possible through the use of special character keys, and in which, generally, a limited amount of columnar accumulation is also possible, is used widely in certain classes of posting work, notably in banks. In the case of one well known machine of this type, however, 27 accumulations are possible, but with totals indicated only. Four of the well-known manufacturers of bookkeeping machines produce both the typewriter and adding machine types, or a combination of such types.

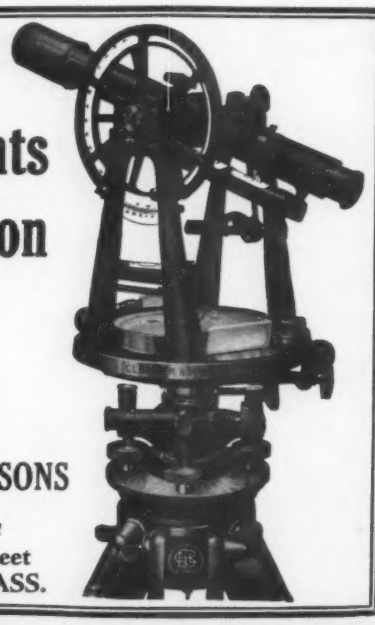
Tabulating Machines:

Machines of this type are operated through the medium of cards into which holes have been punched. Holes are punched in a card, say from an original source of information such as a sales invoice, or an employee's time card (in the latter case often the tabulating card itself) and represent the figures shown on the original information. When the card is fed into the tabulating machine, the punched holes permit electrical contacts, or a mechanical operation, which, in turn, operates the computing and printing mechanism and prints the desired information in detail. A reasonable daily production per operator is approximately 2,500 cards of forty five columns, punched in each column.

The cards having been punched, it is necessary to arrange them in sequence with respect to the nature of the information desired. This operation is performed automatically by a sorting machine at the rate of approximately 400 cards a minute. As an example, in order to arrange a group of cards in numerical sequence according to Commodities, it would be necessary to run all the cards through the sorting machine four times. Such operations would result in an arrangement of cards from 1 to 9999, and with all cards for the same commodity together in a group. It is then possible through the use of these cards in the tabulating machine to produce the desired printed report. From the cards, representing the sales invoices for a specified period, there may be obtained, for example, sales to each customer, expressed in dollars and pounds, as well as the amount of freight paid on the sales to each customer, and also the total sales, the total weight, and the total freight for the period; sales expressed in dollars and pounds of each commodity, and of each size of each commodity; sales by each salesman; sales according to geographical location; and other data. The tabulating machines operate at speeds of from 75 to 150 cards per minute.

From the foregoing example, the possibilities of tabulating machines in the field of standard costs and budgets, production control and statistics, chain store accounting, railroad and public utility accounting, insurance accounting, and in other fields, may be visualized quite easily.

Standard Instruments of Precision



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Recent developments designed to broaden the field of application, and to increase productivity of tabulating machines, have been numerous. In the last three or four years a few of the developments have been:

Alphabetic Tabulation—permitting direct rather than numerically coded descriptions, etc.

Direct Subtraction—eliminating the necessity for complements. Combination of a punch with a billing machine—producing punched cards automatically as sales invoices are prepared.

Summary Card Punch—in conjunction with a tabulating machine producing punched cards automatically, which summarize the information contained on many detailed cards, eliminating the necessity for retabulating and also conserving filing space.

Reproducing Punches—automatically reproducing cards already punched.

Interpreting Punches and Printing Punches—automatically interpreting and printing at the top of the card, the information which the punched card carries.

Cross-footing and Multiplying Punches—from factors punched in the card automatically multiplying and adding and punching the result in the card.

From the foregoing brief discussion of tabulating machines and other accounting machines of more simple construction, it may be concluded, perhaps, that in many respects the primary operation in tabulating machine accounting, viz: punching the card, corresponds to the operation which in simpler machines accomplishes the results directly. It may be deduced also then, and correctly, that in cases where tabulating equipment has been found particularly adaptable, the advantage in a specific application which tabulating equipment may have lies chiefly in its ability to produce and print from the same card several necessary types of reports or classes of information, indicated previously under the discussion of the punched card.

The tempo of development of accounting machines is set by the demands of industry for sound, current facts upon which to base policies. In view of what has already been accomplished, together with what is suggested by the leading accounting machine manufacturers, as possibilities of the near future, there seems to be little doubt of the ability of accounting machines to keep pace with the demands of business and we may expect, with confidence, further striking improvements in accounting machines no less important than those of recent years.

PUBLIC WORKS ADMINISTRATION

(*Continued from page 149*)

Each division under the respective director has engineering, financial and legal divisions.

Each division under the respective director has engineering, financial and legal examiners, who in their division make a complete analysis of each and every application submitted. These examiners, each specialists in their particular department, study purposes, policies and functions also the ability of the applicant as to security and repayment of the loan.

A joint report is prepared by the three divisions and if all concur it is referred to the Special Board presided over by the Administrator who approves or disapproves the loan or grant to the applicant.

A board known as the Technical Board of Review receives projects that have not been approved by any one of the three divisions and upon which the joint report has been unfavorable. The proponents of the project are given a hearing to make sure that there is no possibility of overlooking any angle that might place the project in a more favorable light. If the board is unable to report favorably the applicants are notified that no loan or grant can be made.

After approval of the project by the Special Board of Public Works the applicant is notified and a bond purchase contract is drawn up for the signature of the applicant and the Administrator. The applicant is then in the position to furnish bonds after approval by the bond counsel to the Administrator through the agency of the Federal Reserve Banks, and receive the necessary funds to carry out the work. The work will be carried out under the supervision of the State Engineer and Chief Inspector.

This program will automatically select the most worthy and desirable projects. Naturally, all projects submitted have the backing of the local communities presenting them and are considered most essential to their welfare; each community realizing they eventually have to pay for these added improvements. In distributing these projects throughout the country particular attention has been given to prorated allotments by states and to centers of unemployment.

The Administrator and his organization have labored day and night to allocate this money as equally and quickly as possible. Applications have come in far in excess of amount available. The full effects of the Public Works program has as yet not been felt. When it finally strikes its full swing the impetus to all branches of industry and to consumer buying power will be tremendous. The manifold branches of labor and the varied commodities, which will be utilized in so vast a program will give employment to practically all types of workers whether directly on the job or in the manufacture of materials for the jobs. That is one of the main reasons why this Public Works program is bound to lift the country out of this depression. It is the greatest measure to employ men that could have been devised.

President Roosevelt knew that only such a vast and varied program could start the wheels of the Construction Industries once more. The criticisms leveled at the Public Works Administration were most unjust and unfounded. The volume of allotments and the speed with which this program has been pushed is due to the dynamic personality, comprehension and untiring energy of the Public Works Administrator, Secretary of the Interior, Harold L. Ickes and his Deputy Administrator Colonel Henry M. Waite. It should be a source of great pride to all Tech men to know that Colonel Waite is a Tech alumnus, class 1890. His many achievements and his varied experience, admirably endowed him with the qualifications necessary to his complex office and duties.

At present, practically the entire $3,300,000,000 has been allocated. Congress, at its next session, will decide whether it wishes to set up a further suitable sum to carry out the many worthwhile projects daily arriving at the Public Works headquarters in Washington, D. C.

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CABLE-GRAM

It's not easy to tell you how, for many years, G-E chemists have been fiddling around with Glyptal (a synthetic resin of the alkyd type, made from phthalic anhydride and glycerine as base materials); or how, in studying high-molecular-weight organic compounds, they found that the flexibility of Glyptal could be varied by changing the length of the chains of the polyesters—ho, hum! But you may be interested in knowing that Glyptal compounds make excellent printing rolls, tooth-brush handles, gaskets, ash trays, automobile finishes, and—what not.

These chemists not long ago turned out Glyptal-cloth insulation for cable. Soak it in oil; it won't care. Heat it to 200 degrees F., if you wish. Its resiliency is remarkable; its tenacity, terrific; its durability—it makes other insulations seem like wrapping paper.

"X-RAY AS YOU GO"

It's just the thing for customs inspectors, veterinarians, baggage men, and detectives—this new portable x-ray announced not long ago by J. H. Clough, U. of Rochester, '16, new president of the G.E. X-Ray Corporation.

The set can be toted around easily, and operates, safely, from an ordinary light socket. It will make x-rays of the human body, industrial fluoroscopic examinations, and radiographs of locked trunks, suspicious packages, and the like. It is particularly adapted to making x-rays of animals and for use in cases where the machine must be moved to the patient. A layman can operate it easily and with safety.

It brings the x-ray within practicable reach of the veterinarian. The first set built was rushed from exhibition at Chicago to Belmont Park, and there used to inspect the right forefoot of one of the best-loved horses of the modern turf, which was on the point of being prematurely retired for a puzzling lameness. So simple and quiet was the operation of the x-ray that the horse was not in the least nervous. "Well, well, boys," neighed Equipoise, "I'm sure glad you came along."

99.9909% PERFECT

Soap that's "99.44 per cent pure" may be pretty good, for soap; but in the matter of reliable control of street lights—well, lend your ears.

Carrier current controls the street lighting in one district of Springfield, Mass. In the last year there have been but 32 failures (from all causes, lightning included) in 350,928 controller operations. That's within .0091 per cent of perfection.

Carrier current makes use of wires and transformers already installed, avoiding duplication and congestion of circuits. In Springfield, a 700-cycle current, transmitted for eight seconds, operates 481 controllers, turns on 675 lights. Used 30 seconds, it turns them off. A second frequency of 460 cycles is available to control off-peak water heaters and other devices. This is the only G-E installation of its kind—a temporary distinction, we hope.

C. E. Jennings, Ohio State, '12; F. M. Rives, U. of Texas, '23; and J. L. Woodworth, U. of Idaho, '24, were responsible for this job.

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